RESEARCH DEPARTMENT

Tropospheric propagation measurements over mixed land and sea paths at 560 Mc/s

RESEARCH REPORT No. K-180

1965/29

THE BRITISH BROADCASTING CORPORATION
ENGINEERING DIVISION

RESEARCH DEPARTMENT

TROPOSPHERIC PROPAGATION MEASUREMENTS OVER MIXED LAND AND SEA PATHS AT 560 Mc/s

Research Report No. K-180

(1965/29)

E. Sofaer, A.M.I.E.E.
J.W. Stark, C.G.I.A., A.M.I.E.R.E.

D. Maurice

for Head of Research Department

Research Report No. K-180

TROPOSPHERIC PROPAGATION MEASUREMENTS OVER MIXED LAND AND SEA PATHS AT 560 Mc/s

September 1965

Research Report No. K-180

(1965/29)

TROPOSPHERIC PROPAGATION MEASUREMENTS OVER MIXED LAND AND SEA PATHS AT 560 Mc/s

SUMMARY

Field strength measurements of a transmission at 560 Mc/s were carried out over mixed land and sea paths at distances ranging from 198 km to 356 km. The results show that the attenuation, relative to an all-sea path, introduced by sections of land at the end of the path increases with distance from the coast. A method of estimating the attenuation due to the presence of land in the path is proposed.

1. INTRODUCTION

During the past decade the BBC has carried out a series of long-distance propagation measurements[1,2,3,4] over land and sea paths at frequencies in Band IV (495 and 560 Mc/s) and Band V (774 Mc/s). The measurements were submitted to the International Radio Consultative Committee (CCIR) and used, in conjunction with data from other United Kingdom and overseas administrations, to derive the separate over-land and oversea field-strength/distance curves given in CCIR (Geneva 1963), Recommendation 370[5]. These curves are used by broadcasting authorities in problems of channel sharing.

The CCIR overland curves relate to transmission over paths lying entirely over land, and the oversea curves to paths entirely over sea. The CCIR also provide, in Report 239 (Annex)[6], curves which enable estimates of field strength over mixed land-sea paths to be made. In the procedure advocated a field strength estimate is first made as if the path is entirely over sea, and corrections for the land sections of the path, derived from the curves[6], are then applied. In most cases the land sections occur at the ends of the path and two corrections are required, one for the land distance from the coast to the transmitter, and the other for the land distance from the coast to the receiver. If these distances are sufficiently long, the correction given by the curves[6] will reduce the estimated field strength to a value below that indicated by the land curve. For such cases, the correction has been limited by an arbitrary rule that rejects a land-sea estimate in favour of an all-land estimate if the former is lower in value.

The CCIR procedure was based on a very limited number of measurements, and in order that more data may become available, it was decided to undertake a systematic experiment to examine the law of attenuation with distance inland from the coast.

The BBC, in conjunction with the Netherlands Postal and Telecommunications Service, carried out mixed land and sea path measurements from 8th March 1963 to 30th June 1964. The transmitting site was at Scheveningen in Holland, and five receiving sites were situated in England from the North Sea coast in East Anglia to the Midlands. A map, showing their locations appears in Fig. 1.

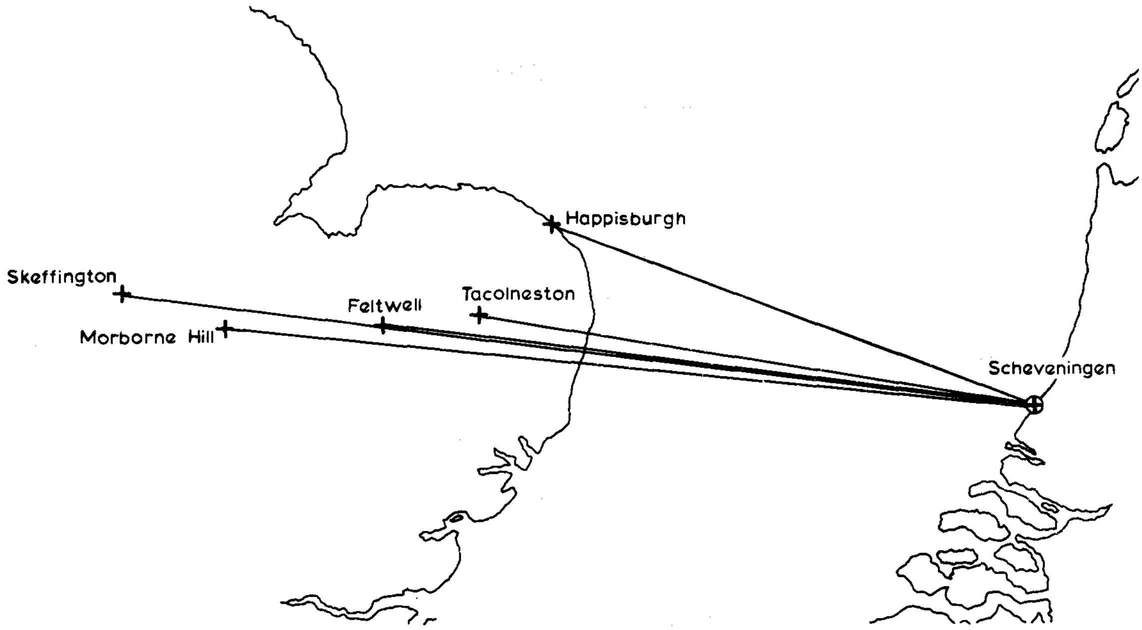

Fig. 1 - Location of sites

2. TRANSMITTING AND RECEIVING SITES

2.1. Transmitting Sites

A Band IV transmitter operating at 560 Mc/s was installed and operated by the Netherlands Postal and Telecommunications Services at their Scheveningen Radio Station. The transmitter was square-wave modulated at 1000 c/s to a depth of 100%, the modulation being cut for two seconds every minute for the purpose of identifying the signal at the receiving sites.

The transmitting aerial was a two-tier five-element Yagi with a screen reflector. Its intrinsic gain relative to a $\lambda/2$ dipole was 13 dB and its half-power beamwidth $\pm$ 23°. Further transmitting site details are given in Table 1. The daily schedule of transmission was 0830 to 2300 hours, British local time.

2.2. Receiving Sites

The coastal site, which was the reference site, was at Happisburgh (Norfolk); the inland sites were at Tacolneston (Norfolk), Feltwell (Norfolk), Morborne Hill (Northamptonshire), and Skeffington (Leicestershire). Fig. 1 shows their location and Table 2 gives additional receiving site details.

TABLE 1

Transmitting Site Details

TRANSMITTING SITE*	SITE HEIGHT a.m.s.l.		AERIAL HEIGHT a.g.l.		AERIAL POLARIZATION	LATITUDE	LONGITUDE
	ft.	m.	ft.	m.			
Scheveningen	43	13	155	47	Horizontal	52°06'N	04°16'E

* The distance of the transmitting site from the Dutch coast is zero miles (km).

TABLE 2

Receiving Site Details

LOCATION	DISTANCES ALONG THE PATH						SITE HEIGHT a.m.s.l.		BEARING OF SITE FROM TRANSMITTER °E OF TRUE NORTH	LATITUDE	LONGITUDE
	LAND		SEA		TOTAL						
	ml.	km.	ml.	km.	ml.	km.	ft.	m.			
Happisburgh	0	0	123	198	123	198	50	15	295	52°49'42"N	01°31'38"E
Tacolneston	26	41	109	176	135	217	210	64	284	52°31'03"N	01°08'25"E
Feltwell	51	82	109	176	160	258	50	15	281	52°28'50"N	00°31'15"E
Morborne Hill	87	140	109	176	196	316	184	56	280	52°30'26"N	00°20'30"W
Skeffington	113	182	108	174	221	356	690	210	281	52°37'21"N	00°54'28"W

The u.h.f. receiver used for the measurements has been described in a Research Department Report[7]. Its main features were high sensitivity and gain stability. The recording law was approximately logarithmic, with a signal range of about 50 dB. This range was insufficient to accommodate the rise in field strength that occurred in conditions of intense abnormal propagation, and it was arranged that during these abnormal periods a 30 dB attenuator would be brought into circuit between the signal and intermediate-frequency units.

The type of receiving aerial used at all the sites was a ten-element Yagi having an intrinsic gain of 10·5 dB relative to a $\lambda/2$ dipole, and a half-power beam-width of ± 22°. The aerial heights were 30 ft (9·1 m) above ground level.

The recorder charts were run at a speed of 3 in. (76 mm) per hour or 6 in. (152 mm) per hour depending upon the type of fading normally occurring at these sites.

3. RESULTS

3.1. Analysis

The records of the measurements for each transmission path were analysed to determine the length of time during which the signals exceeded various levels of

field strength. These time durations, expressed as percentages of the overall valid recording time, were then plotted against field strength in decibels relative to 1 μV/m (dB(μV/m)) for an effective radiated power (e.r.p.) of 1 kW. The field strengths for the 0·1, 1, 5, and 10 time-percentages were then obtained from the field strength/time-percentage curve for each transmission path.

3.2. Variation of Field Strength with Time

Fig. 2 gives the results of the analysis for each of the receiving sites. The table accompanying Fig. 2 gives the total hours recorded at each site, as well as the free-space field strengths for the transmission paths.

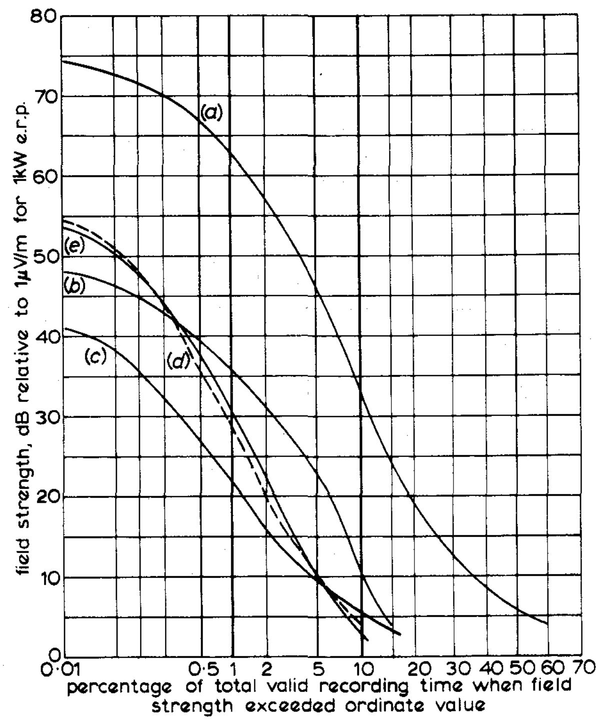

Fig. 2

Field strength distributions at the different receiving sites

CURVE	RECEIVING SITE	TOTAL DISTANCE km	TOTAL HOURS RECORDED	FREE SPACE FIELD dB(μV/m) FOR 1 kW E.R.P.
(*a*)	Happisburgh	198	6255	61·0
(*b*)	Tacolneston	217	6254	60·2
(*c*)	Feltwell	258	5849	58·7
(*d*)	Morborne Hill	316	5630	56·9
(*e*)	Skeffington	356	5459	55·9

Field strengths exceeded for specific time percentages, namely 0·1%, 1%, 5%, and 10% were extracted from Fig. 2 and are given in Table 3. Also given in that table are the land and sea distances for each path and the total length of the path. The

TABLE 3

Results of Measurement

CURVE (FIG. 2)	RECEIVING SITE	DISTANCE (km)			FIELD STRENGTH, dB REL. TO 1μV/m FOR 1 kW E.R.P. EXCEEDED FOR STATED TIME PERCENTAGE			
		LAND	SEA	TOTAL	0·1%	1%	5%	10%
(*a*)	Happisburgh	0	198	198	71·5	62·5	46·5	33·0
(*b*)	Tacolneston	41	176	217	44·5	35·5	22·5	11·0
(*c*)	Feltwell	82	176	258	35·5	22·0	9·5	5·5
(*d*)	Morborne Hill	140	176	316	48·0	28·5	10·5	4·0
(*e*)	Skeffington	182	174	356	48·0	30·5	10·5	3·0

0·1% and 1% field strengths show that the attenuation of field strength over the Tacolneston path is greater than over the Happisburgh path by 27 dB, although the difference in the lengths of the two paths is only 19 km. Another feature that may be noted is that the Skeffington field strengths for time-percentages between 0·1 and 5 are higher than at Feltwell. The Skeffington results are discussed in later sub-sections.

3.3. Receiving Site Variation Factor

The receiving sites are not always representative of the areas in which they are situated and site variation factor (s.v.f.) measurements are made in order that the measured field strengths may be corrected to correspond to values for 50% of locations. Signals at the inland sites were received for only a small percentage of the total time, that is, during abnormal propagation conditions; the s.v.f. measurements could not therefore be made except during these conditions, and it was consequently not possible to measure the s.v.f.'s for all the sites. Some measurements were obtained at Tacolneston, Morborne Hill and Skeffington, and these are given in detail in Appendix I. The measured 1%, 5% and 10% field strengths corrected by the s.v.f.'s are given in Table 4.

TABLE 4

Measured Results Corrected by the Site Variation Factors

RECEIVING SITE	TOTAL PATH LENGTH (km)	FIELD STRENGTH dB(μV/m) FOR 1 kW E.R.P. EXCEEDED FOR STATED TIME PERCENTAGE (CORRECTED FOR S.V.F.)		
		1%	5%	10%
Happisburgh	198	62·5	46·5	33·0
Tacolneston	217	44·5	31·5	20·0
Feltwell	258	22·0	9·5	5·5
Morborne Hill	316	18·5	0·5	- 6·0
Skeffington	356	5·5	-14·5	-22·0

These results show that the s.v.f.'s for Tacolneston, Morborne Hill and Skeffington are respectively +9 dB, -10 dB and -25 dB. No measurements were obtained at Feltwell; but as this site is in flat terrain and overlooks an airfield, it was considered to be a site representative of 50% of locations, and its s.v.f. was therefore taken to be 0 dB. The high positive s.v.f. for Tacolneston is probably accounted for by the Tacolneston aerial being effectively screened by a wood at a distance of approximately 600 ft (183 m). The negative s.v.f. values at Morborne Hill and Skeffington reflect the fact that the sites are well above the surrounding terrain in the direction of reception.

The s.v.f. for Skeffington has an unusually large value. The measurements at this site were made on the 4th and 5th September 1964, when intense abnormal propagation conditions prevailed. This is evident in the results given in Appendix I for this site, where it is seen that the field strengths measured at the permanent site during this period exceed the 1% value on the Skeffington curve in Fig. 2. On two occasions the free-space field strength was exceeded. Since the signals received on the 4th and 5th September 1964 were exceptional, it becomes questionable whether the s.v.f. determined in these conditions is applicable to the field strengths exceeded for the greater time-percentages. Put another way, it is very probable that a different s.v.f. would have resulted if these measurements had been made in less abnormal conditions.

4. ESTIMATES OF FIELD STRENGTH OVER MIXED PATHS

4.1. The Equivalent Distance Method of Making Estimates

The purpose of this experiment was to determine the attenuation relative to an all-sea path, introduced by the presence of land sections in the path. The results show that the relative attenuation increases with distance inland. It may, however, be expected that the rate of increase depends on both the total length of the path and the lengths and distribution of the land sections, and the applicability of the experimental results is therefore restricted to paths with characteristics similar to those of the experiment.

It is reasonable to assume that mixed path field strengths will have values lying between the all-sea and all-land field strengths for the same distances. In order that field strengths over all kinds of mixed paths may be capable of assessment, a method that uses the all-sea and all-land curves has been devised, derived from methods developed for estimating ground-wave field strengths at medium frequencies over composite land and sea paths. An account[8] of the historical developments surrounding the various proposals made in the medium frequency case makes interesting reading. The present method is a modification of the Equivalent Distance Method first suggested by the BBC, and incorporates an averaging procedure originally suggested by Millington. In it the field strength estimates are made in both the forward and reverse directions, and their average taken.

As an aid to understanding the method suggested for u.h.f. calculations, two examples are given in the next paragraph.

4.2. Examples

The curves reproduced in Fig. 3 show 1% tropospheric field strength as a function of distance for oversea and overland paths. The 10% tropospheric curves

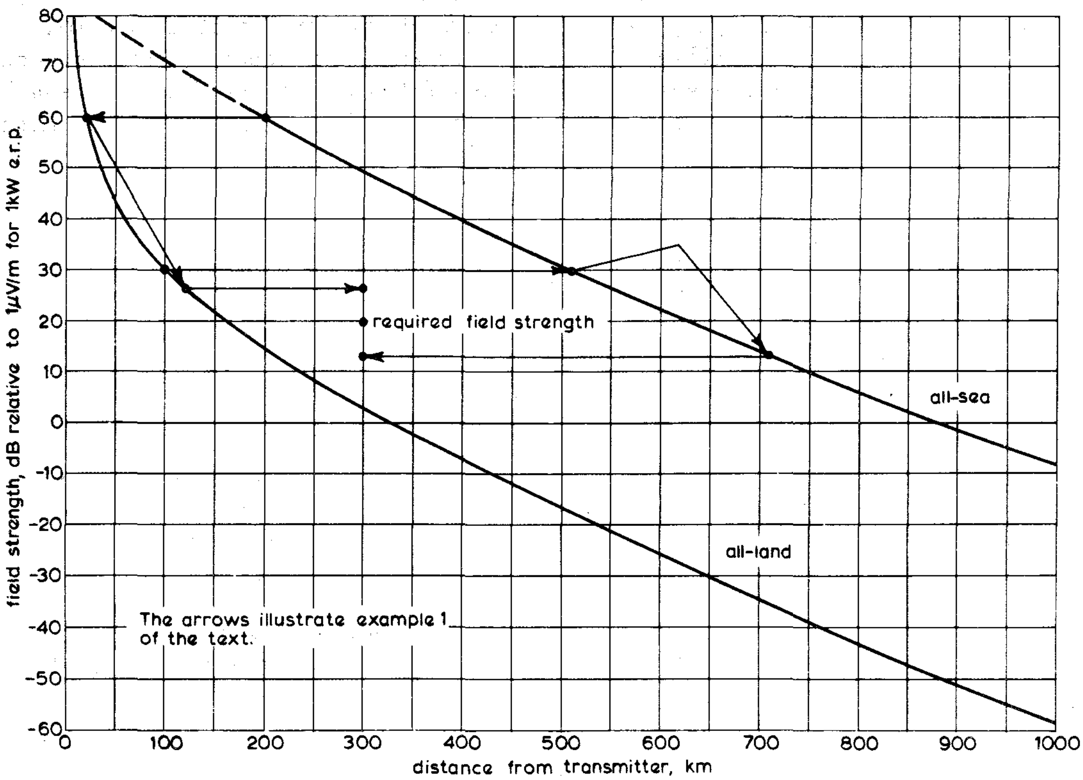

Fig. 3 - Land and sea tropospheric curves (1% time)

are given in Fig. 6. The curves are revised versions of the existing CCIR tropospheric curves[5], and are the subject of a paper submitted to the CCIR by the U.K. Study Group proposing their adoption. They are used to demonstrate the method, as well as to compare the estimated values with measurements.

Let it be assumed, for the purpose of this example, that the transmission path consists of 200 km of sea and 100 km of land, as shown in Fig. 4. In making the calculation, the path is traversed in both directions, and the geometric mean of the two computations taken as the required field strength.

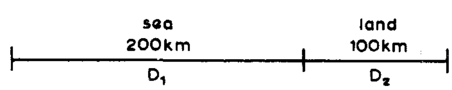

Fig. 4 - Transmission path of Example 1 of the text

Commencing in the direction from left to right in Fig. 4, the all-sea curve in Fig. 3 indicates that the field strength at 200 km is 60 dB (µV/m). The distance along the all-land curve at which this field strength is reached is 20 km. This distance may therefore be called the 'equivalent distance' on the land curve of 200 km on the sea curve, when the field strength is 60 dB (µV/m). It is now assumed that the wave, which has travelled over 200 km of sea, is in the same state as a wave that has travelled the equivalent land distance of 20 km. It will, therefore, continue to be attenuated according to the land curve as it proceeds over the next section of path 100 km long. The equivalent distance of the whole path is thus 120 km, and the field strength at this distance on the land curve is 26·5 dB (µV/m).

The process is repeated commencing from the right of the path. Thus, for 100 km of land, the all-land curve indicates a field strength of 30 dB (μV/m). The equivalent distance on the all-sea curve is 510 km. The equivalent distance of the whole of the path on the sea curve is then 710 km, and the field strength at this distance on the sea curve is found to be 13 dB (μV/m). The geometric mean of the two answers obtained is:

$$E_o = \tfrac{1}{2}(26{\cdot}5 + 13)$$
$$\simeq 20 \text{ dB } (\mu\text{V/m})$$

which is the required field strength.

Fig. 5 - Transmission path of Example 2 of the text

The procedure for paths containing more than two sections is merely an extension of what has been described. In the case of the land-sea-land path shown in Fig. 5, the steps in the computation are as follows:

In the direction from left to right:

Field strength at 200 km on the land curve	14·5 dB (μV/m)
Equivalent distance for 14·5 dB (μV/m) on the sea curve	695 km
Equivalent distance on the sea curve to the end of the next section 200 km long	895 km
Field strength at 895 km on the sea curve	-1 dB (μV/m)
Equivalent distance for -1 dB (μV/m) on the land curve	340 km
Equivalent distance to the end of the path on the land curve	440 km
Field strength at the end of the path	-11 dB (μV/m)

In the direction from right to left:

Field strength at 100 km on the land curve	30 dB (μV/m)
Equivalent distance for 30 dB (μV/m) on the sea curve	510 km
Equivalent distance on the sea curve to the end of the next section 200 km long	710 km
Field strength at 710 km on the sea curve	13 dB (μV/m)
Equivalent distance for 13 dB (μV/m) on the land curve	210 km
Equivalent distance to the end of the path on the land curve	410 km
Field strength at the end of the path	-8 dB (μV/m)

The required field strength is $\tfrac{1}{2}(-11-8) = -9{\cdot}5$ dB (μV/m).

Mathematical expressions for the above procedure are given in Appendix II.

4.3. Comparison of Estimates with Measurement

The oversea sections of the mixed land-sea paths of the experiment were 174 to 176 km in length. Field strength-distance curves estimated by the proposed equivalent distance method for a sea path of 175 km followed by land paths of varying length were derived from the 1% and 10% curves of Figs. 3 and 6. They are the solid line curves in Figs. 7 and 8 respectively. For purposes of comparison the field strengths listed in Table 4, that is, of the measured values corrected by the s.v.f.'s are plotted in the figures. The dashed curve appearing in each is derived by the current CCIR method[6], and is discussed in Section 4.4.

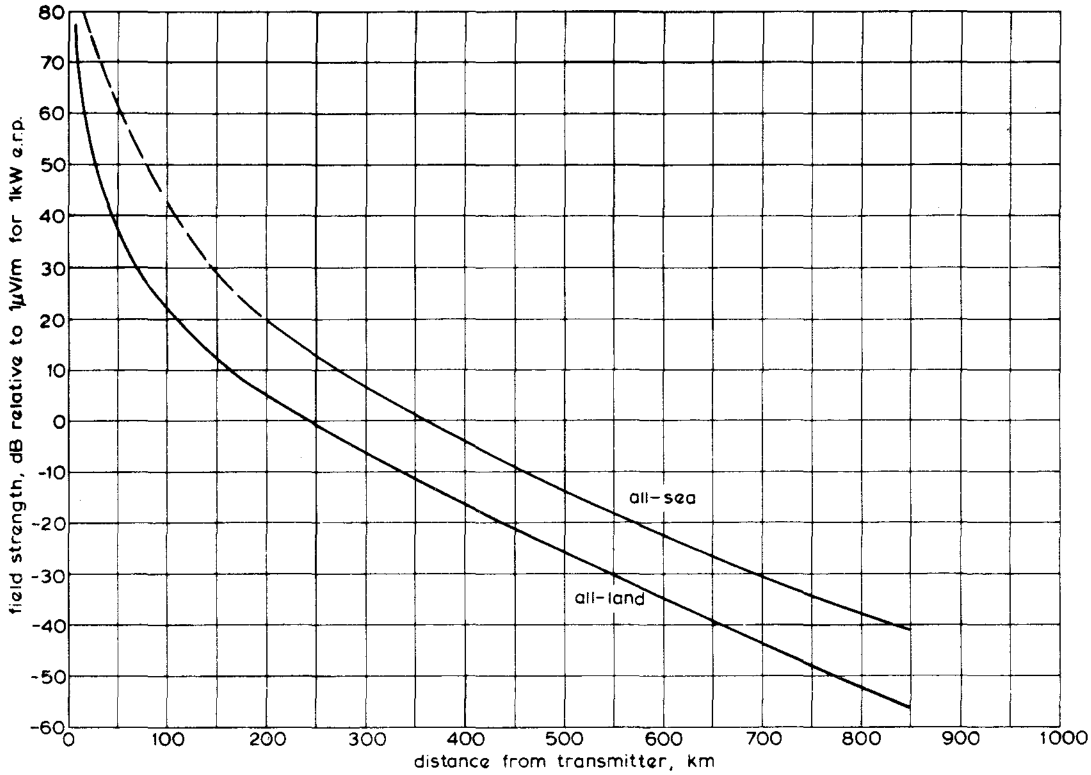

*Fig. 6 - Land and sea tropospheric curves (10% time)**

* See Fig. 3 for the curves relating to 1% time

In Fig. 7 the 1% measured values are in better agreement** with the solid curve than with the dashed curve. In Fig. 8, where the 10% measured values are compared, agreement with the solid curve is not so good; but, neither is it very good with the dashed curve. The Skeffington plot at 356 km in this figure is well outside the region between the oversea and overland curves, being as much as 10 dB below the latter. It was mentioned earlier (paragraph 3.3) that the s.v.f. measurements at Skeffington were carried out during a period of intense abnormal propagation. The value of -25 dB obtained as the correction factor was applied to both the 1% and 10% field strengths at Skeffington, but it appears from Fig. 8 that this correction is too large for the 10% curve. It may therefore be conjectured that the s.v.f. for a site is not a constant factor depending on its location alone, but one which may vary with tropospheric conditions.

** By the method of least squares.

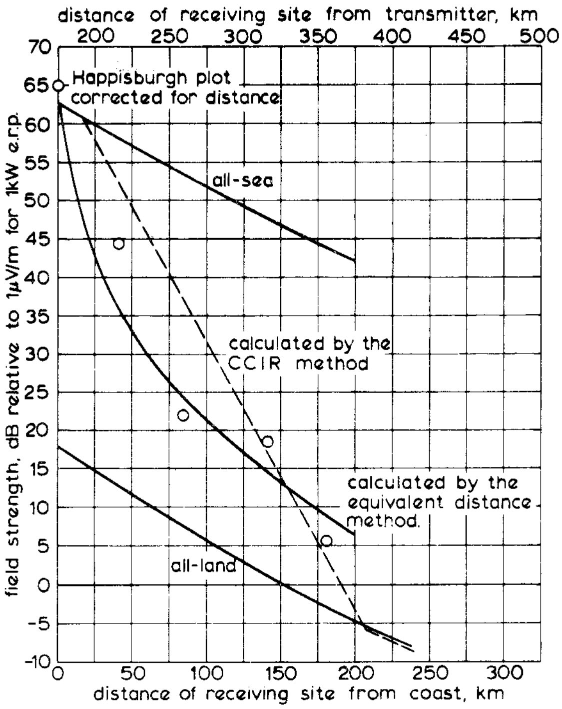

Fig. 7 - Mixed land-sea curves compared with measured values (1% time)

o Measured values corrected for s.v.f.

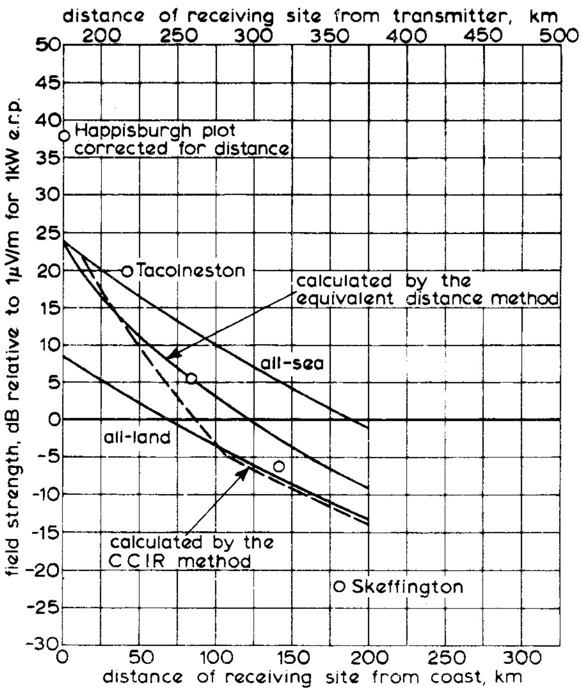

Fig. 8 - Mixed land-sea curves compared with measured values (10% time)

o Measured values corrected for s.v.f.

Another anomaly in Fig. 8 is reflected in the high values applicable to Happisburgh (shown at 175 km) and Tacolneston (at 217 km). The field strength for Happisburgh is 12·5 dB and that for Tacolneston 2·5 dB above the all-sea curve, although the latter site is 19 km inland. These differences can be attributed only to the probability that more favourable tropospheric conditions prevailed in oversea and coastal areas during the comparatively short period of the experiment than during the numerous and prolonged experiments that provided the data for the oversea curves. It is nevertheless noteworthy that these more favourable conditions affected the 10% field strength more than the 1%, since the 1% Happisburgh value plotted at 175 km in Fig. 7 exceeds the oversea curve at the same distance by only 2·5 dB. An explanation of this difference lies in the different slopes at different points on the time-percentage curves. Fig. 2 shows that these curves are less steep at the 1% than at the 10% field strengths. Differences in the percentage duration of abnormal conditions will therefore produce greater changes in the level of the 10% field strength values than of the 1% values.

Accepting these assumptions, it may be said that tolerable agreement has been realised between the calculated curves and the measured values, and that the method described may be expected to give reasonable estimates of mixed path field strengths.

4.4. Comparison with the Existing CCIR Method

The dashed-line curves in Fig. 7 and 8 show field strength as a function of distance for the experimental paths, estimated by the CCIR method[6]. The measured points in Fig. 7 lie closer to the curve estimated by the Equivalent Distance Method proposed here than by the CCIR method. Agreement in Fig. 8 between the measured values and one or other of the estimated curves is, however, not so clear cut. A feature of the CCIR curve is the abrupt change in slope where the mixed path curve meets the overland curve. This form of discontinuity is inevitable in all estimates made by the CCIR method[6] when the land section of the mixed path is sufficiently extended. It reflects an inherent weakness in the method and is an adequate reason for replacing it by one less arbitrary in procedure.

5. CONCLUSIONS

Mixed land-sea path measurements at a frequency of 560 Mc/s show that the attenuation relative to an all-sea path introduced by sections of land at the end of the path increases with distance from the coast. A method has been proposed for estimating mixed-path field strengths, using the published oversea and overland tropospheric wave curves. Estimates made by this method are in reasonable agreement with measured values.

The magnitude of a site variation factor is dependent on the tropospheric conditions prevailing at the time of measurement, and it is therefore not strictly applicable to all the time-percentage values of field strength associated with the site. Its accuracy as a correction factor is presumably greatest for that time-percentage field strength which has resulted from tropospheric conditions similar to those existing at the time when the factor was determined.

6. ACKNOWLEDGEMENTS

We are indebted to the Commanding Officer, R.A.F. Feltwell for facilities provided at Feltwell.

7. REFERENCES

1. 'Long Distance Overland Tropospheric Propagation Measurements at 495 and 560 Mc/s', Research Department Report No. K-149, Serial No. 1960/30.

2. 'Long Distance Overland Tropospheric Propagation Measurements on 774 Mc/s', Research Department Report No. K-155, Serial No. 1962/36.

3. 'Long Distance Tropospheric Propagation Measurements over the North Sea at 560 Mc/s', Research Department Report No. K-163, Serial No. 1963/40.

4. 'Simultaneous Long Distance Tropospheric Propagation Measurements at 560 Mc/s and 774 Mc/s over the North Sea', Research Department Report No. K-178, Serial No. 1965/2.

5. CCIR Recommendation 370, Documents of Xth Plenary Assembly, Geneva 1963, Vol. II, p. 24.

6. CCIR Report 239, Documents of Xth Plenary Assembly, Geneva 1963, Vol. II, p. 137.

7. 'A V.H.F./U.H.F. Field Strength Recording Receiver', Research Department Report No. G-056, Serial No. 1962/8.

8. KIRKE, H.L.: 'Calculation of Ground-Wave Field Strength over a Composite Land and Sea Path', Proc. Inst. Radio Engrs., 1949, **37**, 5, pp. 489 - 496.

APPENDIX I

Site Variation Factor Measurements
Measurements made in the Tacolneston Area

TEST NUMBER	SITE LOCATION	GRID REF. [100 km. Sq. TM(62)]	SITE HEIGHT (a.m.s.l.)		DISTANCE FROM PERMANENT SITE		560 Mc/s TEMPORARY SITE	560 Mc/s PERMANENT SITE	560 Mc/s COMPARISON OF FIELD STRENGTH OF TEMPORARY WITH PERMANENT SITE	SITE DETAILS
			ft.	m.	ml.	km.	dB	dB	dB	
1	Fundenhall	149962	200	61·0	1·1	1·8	29·0	5·0	24·0	Good open site
2	Black Hall Farm	132962	210	64·0	0·2	0·3	52·0	40·0	12·0	Good site apart from a few trees
3	Fundenhall	143961	205	62·5	0·8	1·3	56·5	46·0	10·5	Ground flat but trees in vicinity of site
4	B 1113	152957	197	60·0	1·3	2·1	53·0	36·5	17·5	Good open site
5	Tacolneston Village	140952	180	54·9	0·7	1·1	30·5	36·0	- 5·5	Poor site with trees in front of aerial
6	Tacolneston Village (west)	135951	205	62·5	0·5	0·8	44·5	32·5	12·0	Fairly good site
7	Wattlefield	120960	195	59·4	0·7	1·1	31·5	23·5	8·0	Thick wood one mile in front of aerial
8	Tacolneston Village	146954	175	53·3	1·0	1·6	32·5	41·0	- 8·5	Poor site in depression with trees all round
									Av = +8·75 (+9·0)	

APPENDIX I (cont.)

Site Variation Factor Measurements
Measurements made in the Skeffington Area

TEST NUMBER	SITE LOCATION	GRID REF. [100 km. Sq. SK(43) and SP(42)]	SITE HEIGHT (a.m.s.l.)		DISTANCE FROM PERMANENT SITE		560 Mc/s			SITE DETAILS
							TEMPORARY SITE	PERMANENT SITE	COMPARISON OF FIELD STRENGTH OF TEMPORARY WITH PERMANENT SITE	
			ft.	m.	ml.	km.	dB	dB	dB	
1	Palace Hill	692035	500	152·4	2·9	4·7	- 1·0	31·5	-32·5	Trees in front of aerial
2	Marefield	737081	390	118·9	2·9	4·7	7·5	46·5	-39·0	Railway embankment ¼ mile
3	White's Barn	708072	520	158·5	3·0	4·8	9·5	31·5	-22·0	Good open site
4	Galby	700001	470	143·3	3·1	5·0	10·0	33·5	-23·5	Open site but hill at ¼ mile
5	Goady	747991	400	121·9	2·8	4·5	17·5	35·0	-17·5	Trees in front of aerial a short distance away
6	Tugby	772997	470	143·3	3·2	5·2	40·0	60·5	-20·5	In deep depression
7	Hallaton	789973	380	115·8	5·0	8·0	28·5	59·5	-31·0	Fairly flat
8	Stonton Wyville	741949	325	99·1	5·3	8·5	17·0	51·5	-34·5	Flat open site
9	Burton Overy	682979	450	137·2	4·9	7·9	14·0	43·0	-29·0	Good site on hill
10	Launde	795037	600	182·9	3·5	5·6	1·0	0	+ 1·0	Good site on high ground
									Av = -24·85 (-25)	

APPENDIX I (cont.)

Site Variation Factor Measurements
Measurements made in the Morborne Hill Area

TEST NUMBER	SITE LOCATION	GRID REF. [100 km. Sq. TL(52)]	SITE HEIGHT (a.m.s.l.)		DISTANCE FROM PERMANENT SITE		560 Mc/s			SITE DETAILS
							TEMPORARY SITE	PERMANENT SITE	COMPARISON OF FIELD STRENGTH OF TEMPORARY WITH PERMANENT SITE	
			ft.	m.	ml.	km.	dB	dB	dB	
1	Moonshine Gap	129863	220	67·1	3·0	4·8	+10·0	+ 2·5	+ 7·5	Flat open country
2	Denton	160877	75	22·9	3·0	4·8	+ 1·5	+ 4·0	- 2·5	½ mile west of A1; dense belt of trees
3	Yaxley	182914	25	7·6	3·5	5·6	+ 3·0	+ 2·5	+ 0·5	Open Fen country, railway approximately 1 mile
4	Conington	184859	15	4·6	5·0	8·0	- 2·0	+10·0	-12·0	Trees at 300 yds.
5	Great Gidding	123831	205	62·5	5·0	8·0	+ 2·5	0	+ 2·5	Open site near derelict windmill
6	Ashton Wold	096881	210	64·0	2·7	4·3	+ 1·0	+ 2·5	- 1·5	Flat site with belt of trees at rear
7	Kate's Cabin	128961	45	13·7	3·0	4·8	0	+22·0	-22·0	Low site with few trees and bushes dotted about; high ground ¼ mile away
8	Elton	091948	105	32·0	3·1	5·0	+ 4·0	+16·0	-12·0	Open site but ground rising gradually in front of aerial
9	Nassington	071969	55	16·8	4·9	7·9	0	+ 7·0	- 7·0	Open site but ground rising after ½ mile in front of aerial

APPENDIX I (cont.)

Site Variation Factor Measurements
Measurements made in the Morborne Hill (cont.) Area

TEST NUMBER	SITE LOCATION	GRID REF. [100 km. Sq. TL(52)]	SITE HEIGHT (a.m.s.l.)		DISTANCE FROM PERMANENT SITE		560 Mc/s			SITE DETAILS
							TEMPORARY SITE	PERMANENT SITE	COMPARISON OF FIELD STRENGTH OF TEMPORARY WITH PERMANENT SITE	
			ft.	m.	ml.	km.	dB	dB	dB	
10	Castor	133989	90	27·4	4·8	7·7	+ 0·5	+ 4·5	- 4·0	Flat site but wood at ¼ mile in front of aerial
11	Armston	073860	140	42·7	4·6	7·4	- 2·0	+23·0	-25·0	No trees around, but hill at ¼ mile in front of aerial
12	Cotterstock	042912	90	27·4	5·2	8·4	+13·5	+37·5	-24·0	Good site clear all round, but very high ground at three miles
13	Eaglethorpe	078917	60	18·3	3·0	4·8	+13·5	+36·0	-22·5	Fairly good site but high ground at 1 mile
14	Orton Waterville	153954	60	18·3	3·0	4·8	+35·5	+49·0	-13·5	Good open site
15	New Fletton	186974	30	9·1	5·3	8·5	+ 1·5	+18·0	-16·5	Flat site but houses 200 yds. in front and also to rear and sides
16	Yaxley Fen	204921	10	3·0	4·9	7·9	+ 8·5	+11·5	- 3·0	Absolutely flat all round
									Avg. - 9·7 (-10)	

APPENDIX II

The general expression for determining the field strength appropriate to a mixed path having any number of sections of actual lengths D_1, D_2 ---- D_n km is given below.

Two field strength/distance curves are available, namely the CCIR all-sea and all-land curves.

Let $E = E_1(D)$ be the curve (whether all-sea or all-land) applicable to the section nearest the transmitter, so that the field strength is E dB(μV/m) at a distance D km. Let $E = E_2(D)$ correspondingly express the field strength along the other curve.

Let d_1 along the E_2 curve be the distance equivalent to D_1, which means that

$$E_1(D_1) = E_2(d_1)$$

Suppose also that d_{12} along the E_1 curve is equivalent to $(d_1 + D_2)$, that is

$$E_1\ (d_{12}) = E_2(d_1 + D_2)$$

and that d_{13} along the E_2 curve is equivalent to $(d_{12} + D_3)$ that is

$$E_1\ (d_{12} + D_3) = E_2\ (d_{13})$$

and so on. Then the field strength, calculated as explained in the main text by starting from the transmitter end, is $E_1(d_{1n})$ if n is even and $E_2(d_{1n})$ if n is odd.

Correspondingly, if n is even, the section nearest the receiver is under the aegis of the E_2 curve. Let d_n be the equivalent distance along the E_1 curve, that is

$$E_1(d_n) = E_2(D_n)$$

Suppose also that $d_{n,n-1}$ along the E_2 curve is equivalent to $(d_n + D_{n-1})$, that is

$$E_1(d_n + D_{n-1}) = E_2(d_{n,n-1})$$

and that $d_{n,n-2}$ along the E_1 curve is equivalent to $(d_{n,n-1} + D_{n-2})$, that is

$$E_1(d_{n,n-2}) = E_2(d_{n,n-1} + D_{n-2})$$

and so on. Then the field strength obtained by starting from the receiver end is $E_2(d_{n1})$ for n even as we have supposed; similarly if n is odd, the section nearest the receiver is under the aegis of the E_1 curve, and therefore the field strength obtained by starting from the receiver end is $E_2(d_{n1})$. The required field strength E_0 is thus the average of those obtained by proceeding in each direction, namely

$$E_o = \tfrac{1}{2}\ [E_1\ (d_{1n}) + E_2\ (d_{n1})] \qquad \text{n even}$$

$$E_o = \tfrac{1}{2}\ [E_2\ (d_{1n}) + E_2\ (d_{n1})] \qquad \text{n odd}$$

CHS

Printed by BBC Research Department, Kingswood Warren, Tadworth, Surrey